The GENESIS project: science cases for a large submm telescope

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GENESIS (GENeration and **E**volution of **S**tructures in the **IS**m)

A German-french (ANR/DFG) collaborative project: **https://www.astro.uni-koeln.de/GENESIS**

Objectives:

- Disentangle the relative importance of ***gravity, turbulence,*** and ***radiation*** during the molecular cloud- and star-formation process. Understanding how ***dense structures*** (filaments, cores,..) are forming.
- Identifying the spatial ***scales*** of turbulence dissipation, heating and cooling processes, the HI/H_2 transition.

Approach:

- Observations covering a large parameter space of density and excitation conditions from diffuse gas to giant molecular clouds, including filaments and dense cores. Assembling a large data set comprising ***FIR imaging of dust*** (*Herschel*) + ***THz spectroscopy*** of CII, high-J CO lines, OI,.. (SOFIA) + ***molecular lines*** + ***HI***
- Comparison to SPH and MHD ***simulations***, applying the same ***analysis tools*** (PDFs, △-variance, WWCC,....).
- Apply novel, non-linear methods of signal analysis.

A large southern submm telescope at high altitude and the role of CCAT-prime

High altitude (>5000m) radiotelescopes enable to access high frequencies for line and continuum observations. Fig. 1 shows transmission curves (MOLIERE, Urban et al. 2009) for Cerro Chajnantor (6m CCAT-prime) and the ALMA plateau.

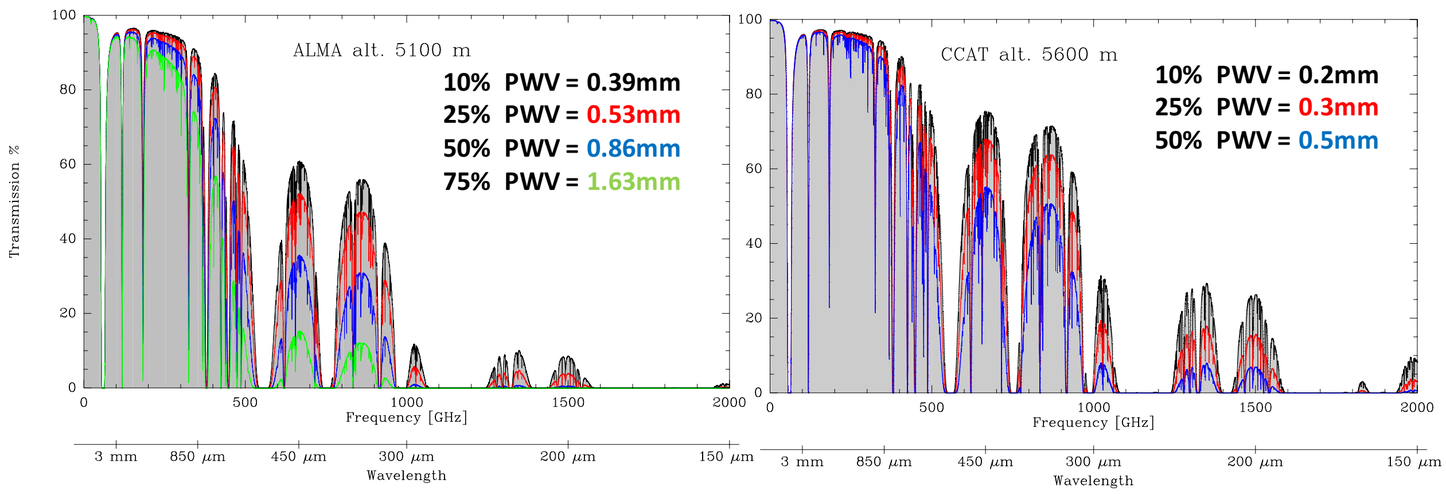

Fig.1: **Atmospheric transmission** for the Chajnantor plateau (left) and Cerro (right) for different values of precipitable water vapour (PWV). See Table 2 for details. The corresponding time decile and quartiles are given. The values are based on satelllite observations and atmospheric modelling with MOLIERE *(Schneider et al. 2009; Tremblin et al. 2012),* and in-situ measurements *(Giovanelli et al. 2001, Radford 2011, 2016).* The Cerro Chajnantor site offers more observing time at low PWV so that heterodyne or continuum observations in the 200 μm window are possible. The ALMA plateau is ideal for observations <1000 GHz.

Science cases for **a large (>20m) submm telescope** at the ALMA plateau site or even higher on Cerro Chajnantor are studies of galactic and extragalactic ISM chemistry and dynamics. Observations of emission lines in star forming regions (mid-J CO, CI, HCN etc.), tracing hot cores, PDRs, outflows, infall, and shocks require high angular resolution (Table 1). Weak lines of light hydrides ($^{13}CH^+$, OH^+) demand high sensitivity. Wide field-of-view cameras (operating at 1 or 2 mm) including polarization should be employed for dust continuum and magnetic field studies.

Species	CO 2-1	SH^+1-0	CO 4-3	CI 1-0	CO 6-5	CI 2-1	$^{13}CH^+$	OH^+
v[GHz]	230.8	345.8	461.0	492.2	691.5	809.3	830.2	909
Use	*low n*	*diffuse gas*	*PDR*	*PDR*	*PDR/shocks*	*PDR*	*TDR/diffuse gas*	
6m	54.3″	36.1″	27.1″	25.4″	18.1″	15.4″	15.0″	13.7″
20m	16.3″	10.8″	8.1″	7.6″	5.4″	4.6″	4.5″	4.1″
30m	10.9″	7.2″	5.4″	5.1″	3.6″	3.1″	3.0″	2.7″
40m	8.1″	5.4″	4.1″	3.8″	2.7″	2.3″	2.2″	2.1″

Table 1: Angular resolution in arcsec for different species and various telescope diameters (n=gas density, PDR=photodissociation region, TDR=Turbulent dissipation regions).

Species CO		2-1	4-3	6-5	7-6	8-7
v[GHz]		230.8	461.0	691.5	806.7	921.8
Cerro	0.2mm	96%	82%	70%	64%	33%
(PWV)	0.5mm	95%	67%	48%	40%	12%
ALMA	0.5mm	95%	60%	46%	38%	10%
(PWV)	1.0mm	93%	58%	32%	24%	4%

Table 2: Atmospheric transmission in % for low- and mid-J CO lines at the Cerro Chajnantor and ALMA plateau sites for different values of PWV.

Synergies

The **GENESIS project** provides GREAT/SOFIA THz spectroscopic observations of the CII 158 μm, OI 63 μm, high-J CO lines to trace ***highly excited PDRs*** and ***shocked gas*** at an angular resolution of 6“ to 20“. It is indispensible to observe the cooling lines of ***warm to cool gas*** (submm and mm molecular lines, CI 1-0 and 2-1) at similar angular resolution to have a complete picture of cloud- and star-formation. **CCAT-prime** is able to map large areas on a regular base with its 64 pixel array CHAI in the mid-J CO lines and the CI 1-0 line. It will be the only ground-based instrument that can observe the NII 205 μm line and high-J CO lines, and will employ a 200 μm camera (p-CAM) for continuum. As a path finder towards larger telescopes, it could demonstrate that one can operate a radiotelescope at the high site which is of relevance for the **AtLAST** project.

The data sets from these projects form an excellent base for science cases for a large submm telescope.

References: *Giovanelli, R., et al*., 2001, PASP 113, 789*; Radford* S., 2011, Astronomical Site Testing Data in Chile, 41, ed. M.Cure, 87; *Radford S. & Peterson J., 2016, PASP, 128, 5001; Schneider N.*, et al. 2009, Planetary and Space Science, Vol. 57, Issue 12, p. 1419; *Tremblin P., et al.,* 2012, A&A 548, 65; *Urban J.,* et al., 2004, J. Quant. Spectros. Radiat. Transfer 83, 529